



Nursery & Garden Industry
Queensland

Management of Nursery Water Storages

Maintaining the best possible water quality in a nursery water storage is essential to provide a safe and reliable irrigation water source. Farm water storages are generally balanced and diverse ecosystems, containing microscopic plants and animals, aquatic plants, and an abundance of larger animals such as fish and insects. The entry of nursery wastewater can severely impact the balance of this ecosystem, providing environmental conditions that can be ideal for the growth of many aquatic weeds and algae.

Monitoring

Monitoring and identifying the quality of the water in a storage facility over time is the first step in ensuring continued appropriate water disinfection, reduced irrigation system blockages, a lessening of staining to structures and stock, and other undesirable effects. pH values above 7.5 may reduce the effectiveness of oxidising agents, particularly chlorine disinfection of irrigation water. Water should be tested regularly and records maintained to provide a history of water quality. Simple pH and Electrical Conductivity (EC) testing can be carried out on-farm, and it is imperative that water is tested by an accredited laboratory at regular intervals to provide a seasonal outline of water quality changes.

Incoming water quality

Waste water from nursery production areas that is channelled into farm storages often contains surplus nutrients, growing media components, pesticides, humic acid and other leached material which can impact on water quality.

The EC levels measured in water storages, nursery runoff and wastewater varies substantially between production nurseries, and appears dependent on the

storage volume and production schedule. The high EC measured at some sites provides an indication of the concentration of ions in the water, reflecting the amount of salt contained in a sample, but it does not identify the type of salts or their individual concentrations. High EC levels commonly affect plant growth by reducing the ability of plant roots to absorb water; eventually causing the plant to wilt and die if not corrected. High EC measurements can also be a result of toxic levels of some individual elements.

Prolonged wet periods can leach nutrients and fine particles from the growing media and reduce oxygen levels in waterlogged containers,



suppressing root development. In the surrounding grassed buffer areas and stock gardens, waterlogging of the soil can also cause a loss of nitrogen through denitrification, and can quickly affect the availability of other nutrients. The anaerobic

bacteria that flourish in waterlogged soils may also secrete toxins that can damage plants. The wastewater runoff from these water-soaked surface areas can be potentially be high in nutrients and other waste products, either dissolved in the water or absorbed on suspended clay or organic matter.

Acid sulfate soils are static when left untouched and waterlogged. Iron sulfides are contained in these sediments and soils, and when exposed to oxygen through drainage or disturbance, produce sulfuric acid. Rainfall events can flush the acid into drainage systems and subsequently into water storage facilities.

High velocity water flows produce significant turbulent action on the sediment layers adjacent

to inflows, clouding the water and reducing the water quality. Reduced oxygen levels in the sediment layer of wastewater storage facilities often provide anaerobic conditions that reduce the rate of waste product breakdown, and the sudden inflows unsettle this sediment and silt. Turbid water becomes warmer as suspended particles absorb heat from sunlight, causing oxygen levels to fall. Turbid water greatly reduces the effectiveness of a number of disinfection and filtration systems.

Iron has been shown to be soluble in water where oxygen supply has been limited, and can be released from disturbed sediments. Discolouration or staining of structures and plant leaves can be a result of high iron levels in the water. This discolouring of plant leaves can be harmful to plants due to reduced photosynthesis and plant transpiration. Elevated iron levels can also interfere with chlorine disinfection of irrigation water.

Sediment and floating trash traps can be used to reduce the amount of particulate matter entering a water storage, and constructed reed bed systems can be used to biologically strip nutrients from drainage water and reduce nutrients in water storages.

Stratification

Stratification, or layering of the water body, occurs mainly in summer and winter, with biological activity in the uncirculated bottom layers using up available oxygen, resulting in iron and manganese being dissolved, and also the production of hydrogen sulfide. The surface or top layers are at the same time often found to have pH values of between 9 and 10. Ideally the best quality irrigation water is drawn from a level between these top and bottom layers. However, as storage levels begin to fall, water can sometimes be drawn from the uncirculated bottom layers.

Algae

Algae are small to microscopic plants capable of growing very quickly in certain conditions. These rapid increases in algal populations, referred to as 'blooms', are most often seen as changes in colouration of the water, or as a scum on the water

surface. The most noticeable indication of the presence of algae is a discolouration of the water. Green colouration is the most common, but there are also brown algae that can be mistaken for sediment.

All algal blooms in irrigation water storages have the potential to cause water management concerns. Algae can clog irrigation systems, obstruct foot valves, congest filters, affect water disinfection, and cause odour problems. Some algae may be toxic, and as algae die their decomposition diminishes the oxygen level in water storages, and noxious gases such as hydrogen sulfide can be produced. Algae also increase the turbidity, or cloudiness of water and increase pH levels, in turn reducing the effectiveness of water disinfection treatments.

Blue green algae are a specific type of bacteria called cyanobacteria, which behave similarly to green algae. Cyanobacteria are of particular concern to human health, as they release toxins into the water as the cells die, and can cause liver or nerve damage if present in drinking water.

There can be seasonal variations in algal blooms due to changes in temperature and light levels. Spring weather patterns, lower storage levels, thermal inversions and wind action can cause the mixing of the layers to produce conditions suitable for algal growth. Algal blooms are most common in spring when water temperatures and light

Table 1: Algae species present in water storages – from *Managing Water in Plant Nurseries*

Common name	Species
Filamentous green algae	<i>Cladophora</i> <i>Hydrodictyon</i> (water net) <i>Spirogyra</i>
Stoneworts	<i>Chara</i> <i>Nitella</i>
Blue-green algae	<i>Anacystis cyanea</i> <i>Anabaena circinalis</i>
Diatoms	<i>Navicula</i> <i>Cycotella</i> <i>Meliorisa</i>
Euglenoids	<i>Euglena</i>

levels in the surface layers increase, but can occur sporadically at any time during the warmer months. Algae requires carbon dioxide and nutrients such as nitrogen and phosphorous, along with increased water temperatures and sunlight to flourish. Algal blooms are not normally a problem in winter with less light and low temperatures, and summer, when water layers do not normally mix. Algal blooms are more likely to occur in storages during the warm, dry and sunny months at the end of summer when the water storage environment has a combination of the following:

- warm water temperatures
- stratified water
- very slow moving or still water
- high nutrient levels (eutrophication)
- high levels of organic matter
- high sunlight levels
- low water levels.

The main nutrients required for the growth of algae are carbon dioxide, nitrogen and phosphorous. Trace elements such as iron, copper and molybdenum may also be important. Fluctuating water temperatures can cause mixing of water layers in the storage, bringing nutrients from the lower layers to the surface.

Problems of water quality and algal blooms can also be minimised by

- cleaning up catchment areas
- installing sediment traps
- using ferric alum

Preventing algal blooms is better than trying to cure a bloom once it has occurred. Controlling the amount of nutrients in the water storage by reducing the amount of organic matter and nitrogen and phosphorous runoff, is the most effective method of managing algae. Blue-green algae are able to fix nitrogen from the air and reducing the availability of phosphorus is therefore

the easier way of controlling these particular organisms. Reducing nutrient levels entering the storage, reducing direct sunlight, and increasing storage depth to reduce water temperature are proactive measures used in the management of algal problems.

When filling a storage, remove all vegetation from below water level, and control run-off from direct sources of nutrients such as animals, septic tanks, disturbed soil and decaying vegetable matter. Detergents can also be a significant source of phosphorous. Removal of unwanted plants in the storage can be a useful long-term strategy to remove nutrients from the system.



Maintaining good water quality by aerating and circulating the water can also assist in preventing or reducing many algal problems.

If excessive algal growth is an annual problem, determine the cause rather than treating the water each year. Test for levels of nitrogen and phosphorous in late winter/early spring to

see if levels are high enough for algal growth, then look at possible sources of nutrients and methods they can be reduced by.

Barley straw may inhibit the growth of algae, and is most useful when applied to storages as a preventative measure due to its slow mode of action, taking at least a month to become effective. 100 grams of straw spread on the surface per 1000 litres of stored water is required, and the effect lasts about six months.

Ferric alum applied at a rate of 100mg/L by suspending the product in a bag in the water has been shown to reduce phosphorous levels by causing the phosphorus to settle out (precipitate).



As a last resort, chemical control can be achieved by the use of copper-based algaecides such as Coptrol®, and is applied by spraying the product over the water surface.

Aeration and circulation

Oxygen dissolved in the water is a major factor in maintaining water quality in any water storage facility, and is utilised by fish and other aquatic organisms as well as the aerobic bacteria that decompose organic matter.

Aeration of lakes, dams and ponds occurs naturally with air exchange at the water surface, through inflows of oxygen rich water from drains and streams, and via the release of oxygen from actively growing aquatic plants. Storages containing nursery wastewater generally need assistance to maintain suitable oxygen levels.

Nursery wastewater storages generally contain high levels of nutrients derived from container leachate that can vary throughout the season. Nutrient rich wastewater can enter the storages during rain events or irrigation, especially after major planting activities, causing algae and aquatic weeds to flourish. Fine organic particles from the growing media are also often introduced into the water storage after rain or irrigation, particularly after planting activities as the growing media settles in the containers. These organic particles add to the turbidity levels in the water before eventually settling on the bottom of the storage and decomposing.

Nursery wastewater storages regularly become thermally stratified, maintaining temperature layers at different depths and not mixing together. The lower layers of stratified water are protected from surface wind movement and wastewater inflows, which maintains the bottom layer as the coldest in summer, and often the warmest during winter. Storages can sometimes invert or turnover during autumn causing the anaerobic bottom layers to come to the surface.

Aeration and circulation removes bottom sediments and breaks up stratification within the storage, increases dissolved oxygen levels, enables controlled removal of organic sediments, and creates an environment unsuitable for algal growth. Aeration within water storages in nurseries is undertaken to improve the water quality and increase the aerobic bacteria population. De-stratifying the storage is encouraged to minimize the development of anaerobic zones that may affect water pH and contribute to algal growths, causing filtration and disinfection issues.

Any process that is capable of adding oxygen to the water could be considered a form of aeration. Air can be introduced into a water storage facility at the surface in a number of ways, to both reduce the stratification and increase the dissolved oxygen.

Aerators can be used in conjunction with a biological activator to enhance the breakdown of suspended solids, increase dissolved oxygen and lower the biological oxygen demand (BOD), ammonia and nitrate levels.

Fountains aerate by collecting the surface water and propelling it into the air via an impeller or pump, to form small droplets with a large surface area, through which oxygen can be transferred before the drops fall back to the water surface. Fountains provide a pleasing aesthetic appearance, however, they produce a limited area of oxygenated water, and provide little de-stratification or circulation of the water.

Paddlewheel aerators, most often used in aquaculture, stir up and splash the water surface

causing oxygen transfer to the disturbed water. Paddlewheel aerators are similar to fountains in producing some degree of oxygenated water with little de-stratification, and also increase evaporation losses.

Bubble aerators introduce air from a compressor onshore through a hose to diffusers located on the bottom of the water storage. The bubbles can be large or small, releasing oxygen into the water as they make their way to the surface, resulting in some localised circulation and mixing of the stratified layers. Small bubble aerators are more efficient in introducing oxygen into the water than large bubble aerators, due to the increased surface area of the bubbles, and longer time taken by the smaller bubbles to reach the surface. However, large bubbles circulate more water causing some mixing of stratified layers.



Circulation aerators utilise an impeller to circulate the water while injecting air into the water stream, usually through a venturi to de-stratify and aerate the water simultaneously. The units are generally mounted on floats on the water surface and can be angled to circulate into the deeper water forcing it to mix with the stratified layers. Circulation aerator systems commonly seen in nursery water storages are designed to fully turn over the water storage three to four times each day. This full turn over can be achieved using off-peak electricity or solar generated electricity. However, during summer when the stratification potential is at its peak, some system operation should be conducted during the daylight hours.

Aquatic weeds

Floating aquatic weeds can cover the entire storage surface causing:

- stratification of the water body
- oxygen depletion
- a reduction in storage biodiversity
- blockages to pumping equipment
- unpleasant odours

Managing or eliminating aquatic weeds from farm storages is not a simple task. Management measures that leave dead or decaying plants in the water can deplete oxygen levels, and can also release large amounts of nutrient, sometimes causing algal blooms. Herbicide applications can also leave the water unsuitable for irrigation purposes for extended periods of time. Always consult the label and seek professional assistance. It is best to manage the floating aquatic weed problem early in the season before it gets out of control:

- monitor the storage regularly
- physically remove plants when they appear
- reduce nutrient levels entering the storage
- use barriers to contain inflow areas.

Floating aquatic weeds such as duckweed (*Lemna* species, *Wolffia* species, and *Spirodela* species) can blanket the entire surface of a farm storage, reducing oxygen levels, and clogging pumping and filtration systems. Duckweed reproduction can be extremely rapid in spring, when water temperature, pH, lighting and nutrient levels are ideal - duckweed can quickly double its biomass in less than seven days. Unlike the leaves of most plants, each duckweed frond or thallus contain buds from which more fronds may grow. Plants may overwinter as dark green or brownish daughter plants called turions, or as seeds, sinking to the bottom of the storage until conditions are suitable for germination.

Wind and wave action in a storage can hinder floating water weed establishment and growth by disrupting their ability to attach themselves to each other and form a dense cover. Aeration and circulation maintains excellent oxygen levels and can disperse some aquatic floating plants hampering their establishment.

Structural Management of Storages

Maintaining water storage infrastructure by regular monitoring and maintenance can help protect storages against the main causes of failure, and increase their useful life. Embankment (storage wall) condition, embankment vegetation, seepage, and spillway condition and function are the four key areas to consider when assessing storages for their structural integrity.

Regular monitoring of both the embankment and the foundations at regular intervals is necessary to detect any problems that may have developed, and allows early corrective action to be taken. During periods when the water level in the storage is high, the embankment should be inspected monthly for evidence of cracks, seepage and movement, with particular attention given to the top of the wall (crest), outside edge of the wall (batter) and adjacent foundation areas. The distance between the water surface and the top of the crest (freeboard) should be maintained at the design level during high flow events, and the water should not be allowed to flow over the top of the embankment. As water levels fall, the inside batter of the wall should be checked for evidence of cracks, slumping, seepage holes, or unusual bleaching. Cracking through the embankment may indicate uneven settlement, while cracks along the storage wall may indicate future slumping of the wall, which may be caused by poor compaction, over-steep batters or excessive seepage.

After periods of high winds, especially on large storages, wave action can erode the inside batter, eventually leaving a vertical face on the inside of the crest. Waves often concentrate in corners, particularly those corners buffeted by prevailing winds. In some instances, continued slumping from the vertical face created can lead to a substantial reduction in crest width, causing problems such as restricted vehicular access. In extreme cases, the crest can be eroded completely, lowering overall storage height, reducing the capacity of the storage and jeopardizing safety.

It is essential to maintain a continuous cover of vegetation on the embankment of the storage to prevent erosion. Self-sown low growing plants may

be allowed to remain if their roots do not pose a threat to the storage, but larger plants can send roots into the core of the storage wall drying it out and creating seepage routes which could ultimately lead to storage failure. Trees on the embankment should be avoided at all costs as tall trees exert large forces on the storage wall and, if blown over, can remove large areas of the embankment. Growth of woody weeds should also be controlled, as excessive growth can prevent full inspection of the storage for leakages or soil slumping. The best option for vegetative cover is to establish a dense grass cover over the inner and outer batters as soon as possible after construction. A layer of topsoil over the bank (to a depth of 150 mm minimum) is essential to maintain a continuous vegetative cover. The crest should be left bare to allow vehicular access if necessary, and to prevent drying of the narrowest part of the embankment. The establishment of good grass cover on the inner batter of the wall prior to initial filling is particularly desirable, and it is important that the grass cover be well maintained and not damaged by herbicide applications.

Severe erosion of by-washes (spillways) and their return slopes are a common cause of failure in gully storages. Most by-washes convey water infrequently but, when flow does occur, a large volume of water is concentrated in a relatively small area. Hence, it is important to maintain a good vegetative cover, but not allow larger plants to grow that will impede water flow. The by-wash is designed to operate as soon as flood flows exceed full supply level, but accumulation of debris in the by-wash can retard the flow of water and lead to water flowing over the embankment, leading to possible failure of the storage. By-washes may require a high level of continued maintenance due to erosion and, if rills (erosion) are evident, they need to be repaired immediately, as eroded areas can quickly extend if left untreated.

Once the storage has been established for a number of years the frequency of inspections may be decreased to annually if no abnormal conditions have been observed. However, any



unusual conditions, which are noted at other times, should be acted upon immediately. For further information, there are publications available from various state authorities on storage construction and maintenance, but it is essential that the services of a professional be sought before any major storage repair works are commenced.

Sealing Leaking Storages

Depending on the particular situation, there are a number of alternatives that can be used to minimise storage leakage.

Clay lining, if suitable clay can be found nearby, can be a cost-effective way of sealing storages. The cost of clay lining depends on many factors, including the transport cost of the clay, the amount of clay to be moved, the cost of emptying the storage, access to the site, and potential crop and income loss caused by emptying the storage. If the storage still holds some water it should be pumped dry and all plants, loose sand and silt removed to expose a firm foundation on which to place the clay lining. There are a number of methods that can be used depending on the nature of the seepage problem, but in all cases, a minimum 300 mm depth of layered and compacted clay at the optimum soil moisture content is used.

Bentonite is a naturally occurring clay and is used in storage building because it swells to many times its dry volume when wet. Bentonite may be used in three ways, depending on the soil type, and whether it is practical to empty the storage. If the storage can be emptied, the area to be treated is

cleared of loose rocks and vegetation and then lightly harrowed.

On light or loam soils, the mixed blanket method is used, where bentonite is broadcast over the prepared area at a rate of approximately 7 kg/m² and then mixed with the first 150–200 mm of soil by light harrowing. The treated soil is then compacted with a roller.

On heavy soils, the pure blanket method is used. Bentonite is spread evenly over the area at a rate of approximately 10 kg/m². The bentonite is then covered with at least 100 mm of site soil and compacted with a roller to prevent the blanket cracking as it dries out.

A third method is the broadcast technique, which can have variable results and is not recommended, but may be the only option if the storage cannot be emptied. In this method, the bentonite is spread over the water surface at a rate of 10 kg/m² and, as it settles to the bottom, it hopefully seals the storage.

There are at least five types of **commercial liners** available to seal leaking storages. They are all flexible membranes, but offer different levels of strength, durability and resistance to UV breakdown. The liners have no structural strength and rely on a continuous backing for support, and must be anchored so they do not move. This means that the soil on which such a liner rests must be well compacted, on an even and not too steep grade, have no vegetation growing in it, and be free from stones and branches which could damage the liner. A layer of fine soil or sand is required under thinner liners and the soil is sometimes sprayed with herbicide to prevent any plants growing through the liner. The simplest way to provide anchorage is to bury the liner in a trench dug around the perimeter of the storage.

Commercially available liners include woven polythene, black polythene, vinyl, high density polyethylene (HDPE), butyl rubber and composites of bentonite and polypropylene.

Woven polythene, in blue or green, resists tearing, but is very susceptible to UV degradation, and will have a life of less than 5–7 years in the sun if it is not protected with a layer of soil. A grade no steeper than 3:1 must be used to keep the soil from slipping off the liner.

Black polythene also has a short life due to UV degradation, and being generally being less than 0.4 mm thick, is susceptible to puncturing, and must be covered with a layer of soil to prolong its life. The two grades of black polythene available use either reprocessed or prime resin. The prime resin liner lasts longer than the reprocessed liner, and the thicker the liner, the longer it will last, because it is better able to withstand the UV degradation of its surface.

Vinyl (or PVC) resists tearing and is more flexible than woven polythene, but also needs to be covered with a layer of soil to minimise UV degradation.

Both HDPE and butyl rubber have the longest life and are tougher than vinyl or polythene products. These liners do not need to be protected from UV exposure, but are more expensive than vinyl and woven or black polythene.

Composite materials contain a thin layer of bentonite sandwiched between polypropylene materials. These products are not UV sensitive, and because of the bentonite material contained within the product, small holes in the liner are self-healing, but these liners must still be covered with soil to protect them from major punctures.

Chemical treatment of soil using gypsum, sodium tripolyphosphate (STPP) and polyacrylamides can be used to seal storages.

Fine grained gypsum is used to stabilise dispersive soils so that both surface erosion and potential tunnelling failures are reduced. The gypsum is mixed into the first 150–200 mm of damp surface soil at a rate of about 2 kg/m², and the treated area is then compacted with a roller.

STPP is a chemical which has the opposite effect to gypsum. It is used to disperse the clay particles in

stable, but porous, clay soils as these soils are very hard to compact, and STPP is used to help the compaction process. Not all clay soils are suitable for STPP treatment and laboratory tests are needed to determine if the soil will react favourably. Treatment using STPP is the same as the bentonite mixed blanket method. STPP, in powder form, is broadcast over the area to be treated at a rate determined from the laboratory tests, usually 0.5 kg/m². With the soil near its optimum moisture content it is then mixed using a rotary hoe and compacted with a roller to give a compacted thickness of about 300 mm. Finally, the area must be covered with untreated soil to prevent the STPP/soil mix from drying out and cracking. STPP is ineffective in sandy soils or soils high in calcium carbonate and, in some cases, may increase seepage due to an increase in tunnelling of the storage construction material.

Polyacrylamide sealants are biodegradable polymers that use the same broadcast method as for bentonite. These chemicals are used at rates of 75–100 g/m², with the recommendation that the storage contains water when treated as this forces the expanding gel into the leaking area to seal it.

Sprayed membranes such as concrete and asphalt can be applied to the area to be treated to form a continuous skin of material that acts to seal the storage, but are rarely used to seal farm storages because of the high cost of the work involved. Sprayed concrete (known as gunite or shotcrete) requires specialised equipment and experienced applicators, as its application involves spraying a mix of water, cement and aggregate onto a graded surface, and steel reinforcement is usually required. Asphalt (bitumen) also requires a prepared, graded surface, experienced applicators and specialised equipment. The process can be messy but no steel reinforcement is required. Both methods require a depth of at least 75 mm to be effective, and are prone to movement cracks and weathering.

There are a number of publications available on sealing leaking storages, but it is imperative that the services of a professional be sought to

Table 2: Strategies to overcome major problems that may be encountered with storages

Damage	Cause	Remedial action
Erosion (rilling) of embankment	Water flowing over embankment.	Pack grass sods complete with soil into any rills formed.
Settlement	Poor compaction of the embankments of new storages.	Check the amount of freeboard as the storage fills. Top-up the level of the crest or lower the spillway inlet.
Cracks through the embankment	Uneven settlement	Cracks through the wall may lead to major failure. Professional advice should be sought.
Slumping and cracks along the embankment	A combination of poor compaction, excessive seepage and excessive steepness of embankment. Cracks running parallel to the crest length can collect rainwater and potentially activate a slide in the embankment.	Cracks along the length of the wall may point to future slumping and this could lead to major failure. Seek professional advice. Any cracks in the embankment should be moistened, ripped to a depth that penetrates into moist or compacted material, then moistened again if necessary. The ripped area should then be rolled and compacted to the original storage profile.
Seepage from embankment	Water moving through the embankment.	Check the upstream face for points where water may enter. Dig-out and repack seepage points on the upstream face of the embankment.
Tunneling through or under the wall.	Seepage lines in tunnel prone materials such as sand will readily turn into tunnels or 'pipes'.	As an interim measure these may be plugged with carefully compacted soil. A bentonite: sand 1:2 mix is sometimes used as a plug.
Vermin damage	Uncontrolled access of burrowing animals.	Dig out burrows and repack with clay based material. Maintain effective vermin control.
Wheel ruts and damage on the crest	Damage to the crest is often brought about by poor maintenance of the crest surface.	Wheel ruts on the crest interfere with surface runoff patterns and may divert water towards the outer batter. The embankment crest should be constructed with a slight grade to the inside to direct runoff away from the steep outside batter. Occasional re-grading of the crest is recommended to avoid such problems.
Pipelines and Valves	The most common site for storage failures is along pipelines through the embankment.	The outlets of pipelines should be inspected for evidence of seepage along the pipe trench. Valves on pipelines through embankments should be operated periodically to ensure satisfactory performance.
Weeds and Trees	Failure to manage vegetation.	A 150 mm layer of topsoil should be placed over the inner and outer batters to assist in the establishment of grass cover. All deep-rooted weeds, shrubs and trees should be removed as they appear.
By-wash damage	Damage to by-wash from erosion or poorly maintained vegetative cover.	Establish and maintain an actively growing, robust and relatively uniform vegetative cover. Fence off area, if necessary, to protect vegetation. Keep the spillway clear of debris, tall grass etc. Consider the installation of a PVC trickle flow pipe to intercept and divert consistent small flows which lead to difficulties in maintaining by-wash vegetation. Repair erosion as soon as damage appears.
Turbidity (cloudiness)	Erosion in the catchment or dispersive materials in the excavation. Nutrients running into the storage can increase algal growth.	Control sediment moving into the storage. Small quantities of sediment and nutrients in catchment flows can be intercepted by a heavily vegetated filter zone immediately upstream of the storage.
Wind damage to embankment	Wave action causing damage to embankment.	Lay stone or establishing runner grasses on the sides of the storage where damage is occurring and consider strategic location of trees and shrubs to act as a windbreak for prevailing winds.
Leakage	Poor construction or porous base materials.	Clay lining of the storage or treatment with Bentonite, polymer sealants or liners.

determine the best option available before any storage remediation works are commenced.

Table 2 summarises the strategies that can be implemented to overcome major problems that may be encountered with storages.

Water Storage Evaporation Mitigation

Open water storages can lose as much as 40% of their water volume from evaporation. Wind is a major contributor to evaporation rates, and well-positioned windbreaks can help to reduce evaporation losses from wind and sunlight.

Transferring water between storages to minimise the surface area exposed to wind can be a useful strategy, and deep narrow storages minimise evaporation losses due to their reduced surface area to volume ratio. Other Evaporation Mitigation Technologies (EMTs) include the use of covers, chemical monolayers and increasing storage wall heights.

Various mitigation technologies will be appropriate in different situations, depending on the surface area of the water storage, location, and storage operational requirements. For example:

- Floating impermeable covers are most appropriate on storages less than 1 hectare in size, with all year round water storage.
- Shadecloth structures would also be most viable on storages with permanent water, and are likely to be limited to less than 5 hectares in area.
- Chemical monolayers would be most viable on large storages (greater than 10 hectares), although they can be used for smaller storages, and where the storage is likely to be dry for significant periods.
- Modular systems are likely to be best suited to medium sized storages less than 10 hectares in area, and can be used on larger storages than can continuous structures.
- Increasing wall height is most appropriate when the wall size is small relative to the amount of water stored.

To assist in the decision whether to use EMTs, the Centre for Agricultural Engineering (CAE) has developed an economic ready reckoner, available at <https://evapadvisor.com/aboutstorage>. This on-line tool can assist in making the decision on whether to install EMTs, and which options are more suitable for a particular situation.

Before deciding if EMTs are worthwhile, the value of production that one Megalitre (ML) of water generates, and the cost of alternative water sources must be known. This enables a comparison between the costs of saving the water, the value of extending the period water can be drawn from the water storage, and the additional production the saved water may achieve. This information also allows a simple comparison of the cost of water saved versus the cost of an alternative supply.

Table 3 is an example of a report generated by the ready reckoner, and suggests a range of costs/ML from lowest to highest for each of the EMTs for a medium sized farm storage. This gives initial guidance on which of the five EMTs may suit the particular situation, and assists in deciding which systems are the most appropriate.

Table 3: Example Evaporation Mitigation Costs

	Performance	Cost	Cost to Save Water (\$/ML)
Impermeable Cover	Good	Low	\$469
	Poor	High	\$5,555
Shadecloth	Good	Low	\$773
	Poor	High	\$4,514
Chemical Monolayer	Good	Low	\$50
	Poor	High	\$1,288
Modular Cover	Good	Low	\$1,166
	Poor	High	\$6,467
Increase Wall Height	Good	Low	\$54
	Poor	High	\$169

Lex McMullin
Farm Management System Officer
Nursery & Garden Industry Queensland